


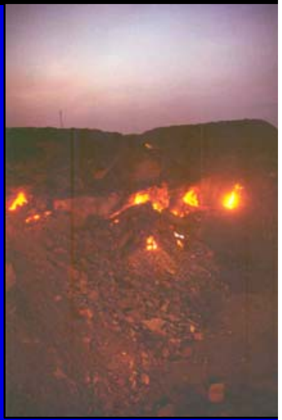


My Experience Grouting Abandoned Coal Mines

by

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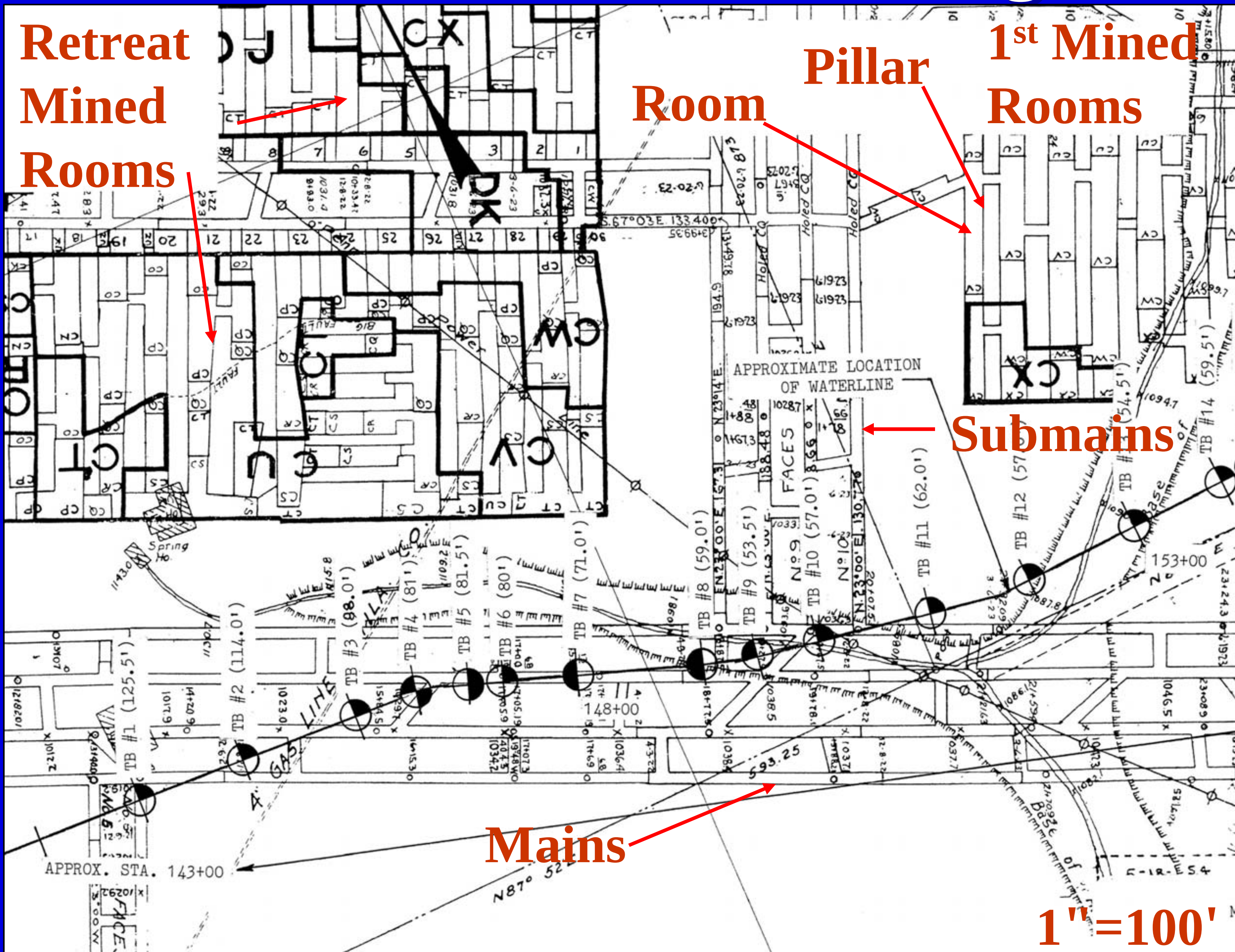
Acknowledgements

- My experience is gained from observations and information from the following individuals who I worked with on these projects: Jack Murray, Jim Kilburg, John Clark, F. Barry Newman, Bob Bruhn, Dick Gray, Bob Turka, Dick Bruce, Stan Michalski, and the late Larry Winschel

Room and Pillar Mining



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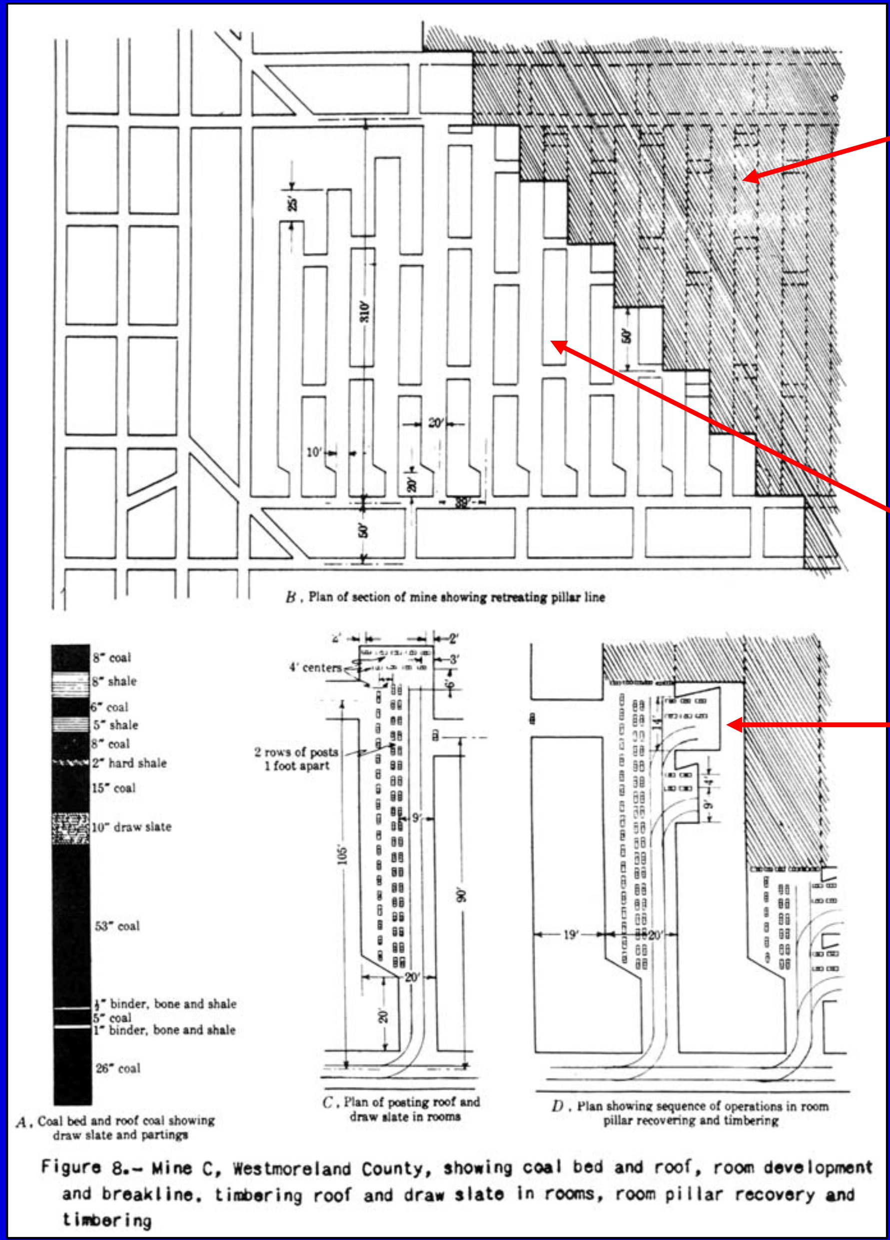
Room and Pillar Mining



Retreat Mine

1st Mine

Remnant

Ref USBM RI 3113, 1931

First Mined Room

Investigations

- Obtain geology information
- Obtain mine map (regional and detailed)
- Obtain literature on mine or mining in area from papers. Information on older mines may be in the "Transactions of the American Institute of Mining Engineers", which became the Society of Mining Engineers (SME) and U. S. Bureau of Mines
- Determine possible subsidence mechanisms – sinkholes and/or troughs, including ground cracks, and anticipated mining conditions
- Develop exploration program.

Investigations

- Test Borings
  - Coring of rock – observe drill tool action, water loss, and condition of core
  - Air Rotary (6-inch dia.) – observe drill tool action and amount of air loss. Also check for air being blown out of adjacent holes, which indicates a connection thorough a mining feature or fracture.
  - Downhole camera – observe condition of rock overburden and mine level conditions. Downhole, side view close-up of sides of borehole, and distance viewing of void areas.
- Geophysical (Surface and downhole)– Varying Results

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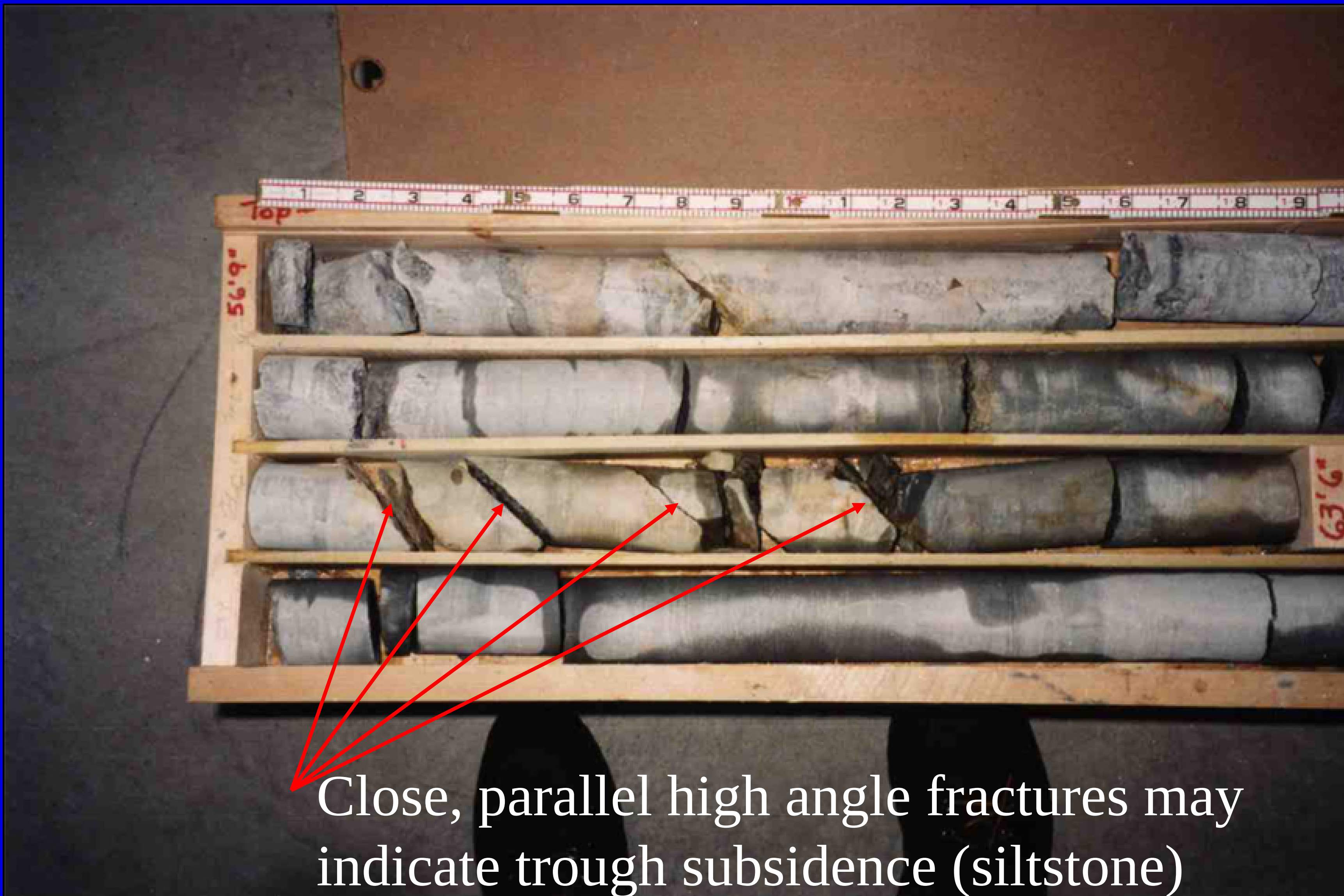
Investigations



Close, parallel high angle fractures may indicate trough subsidence (siltstone)

Close, parallel high angle fractures may indicate trough subsidence (Sandstone)

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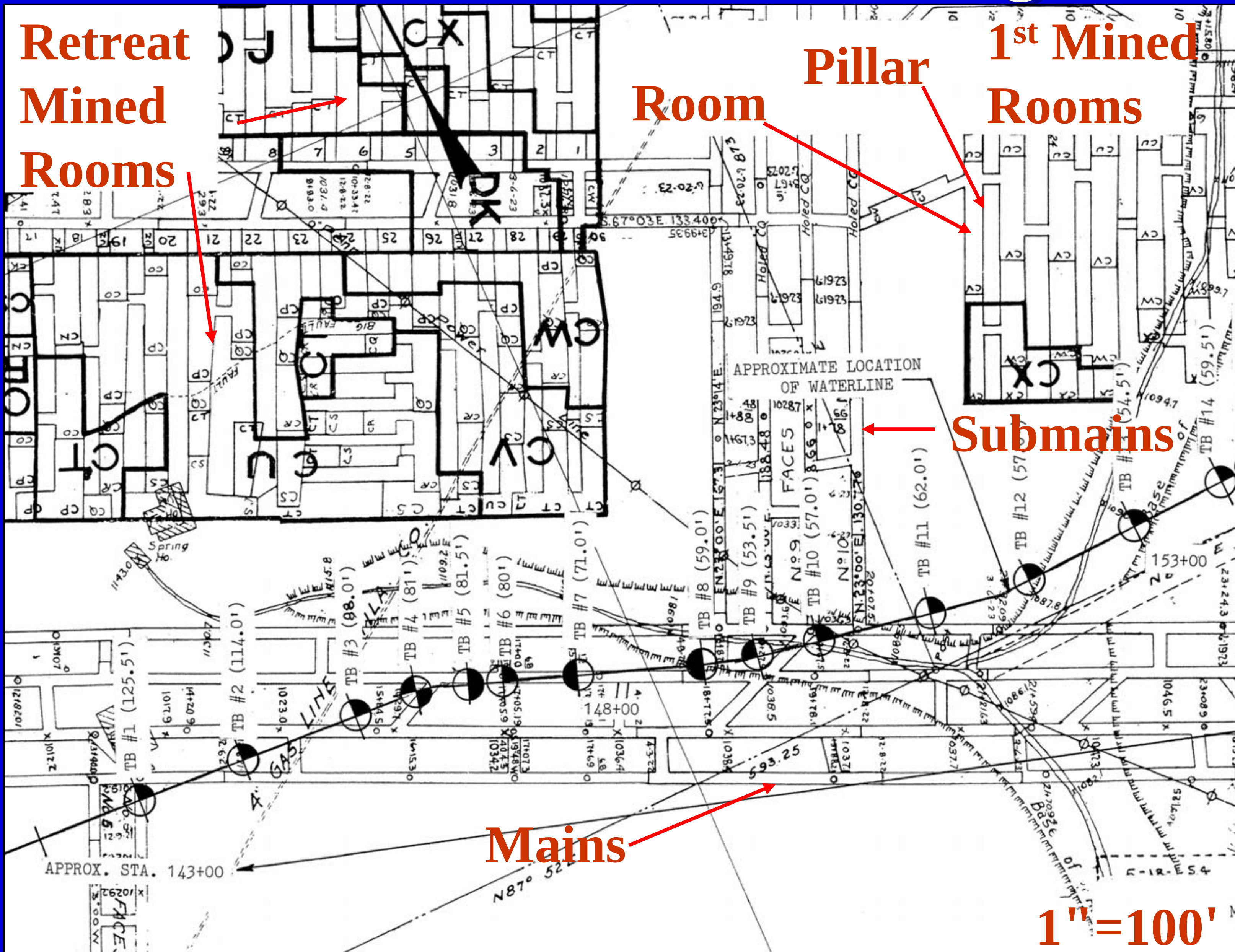
Room and Pillar Mining



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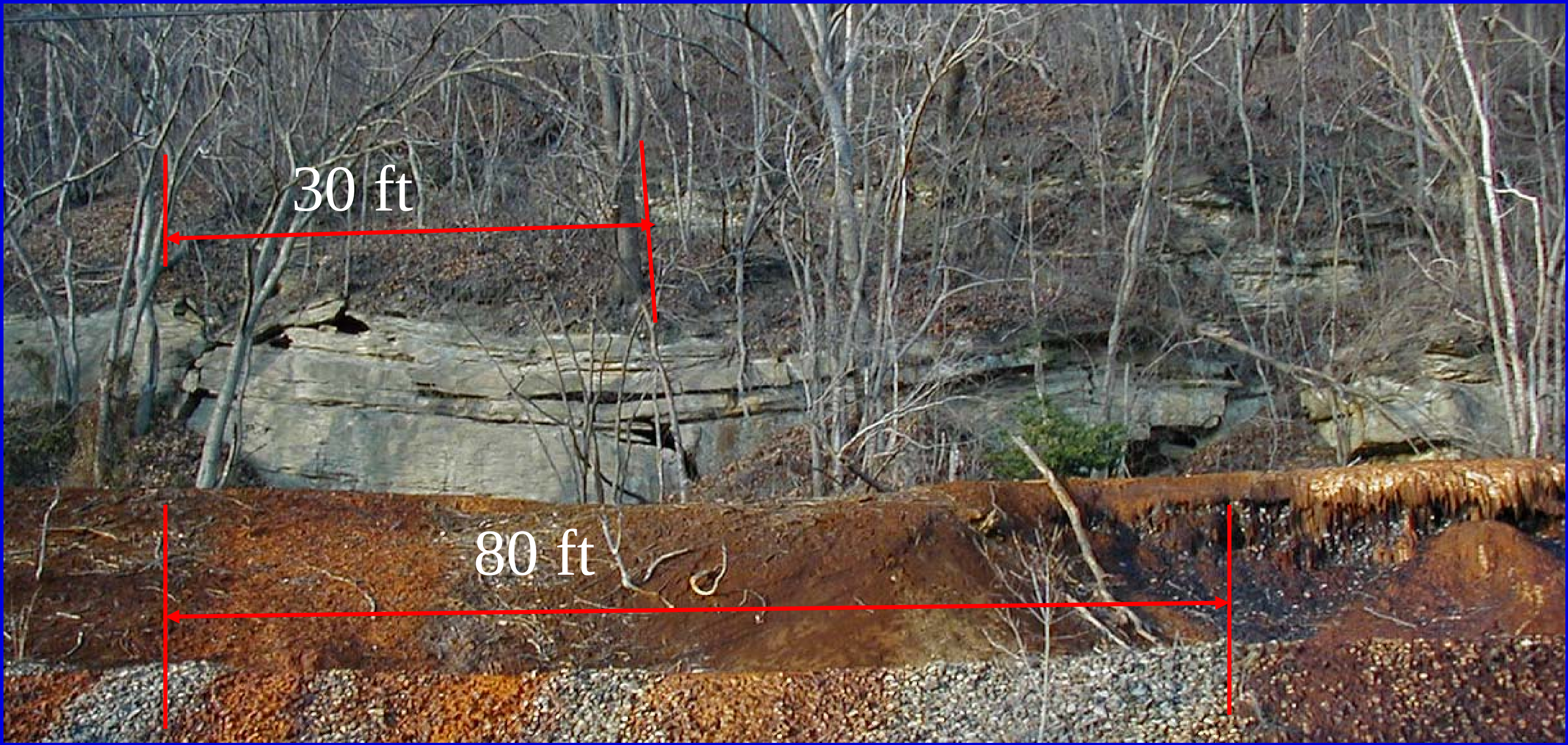
Mine Level Conditions

- Caved/Rooffall
- Roof void
- Gob
- Open Void at mine level

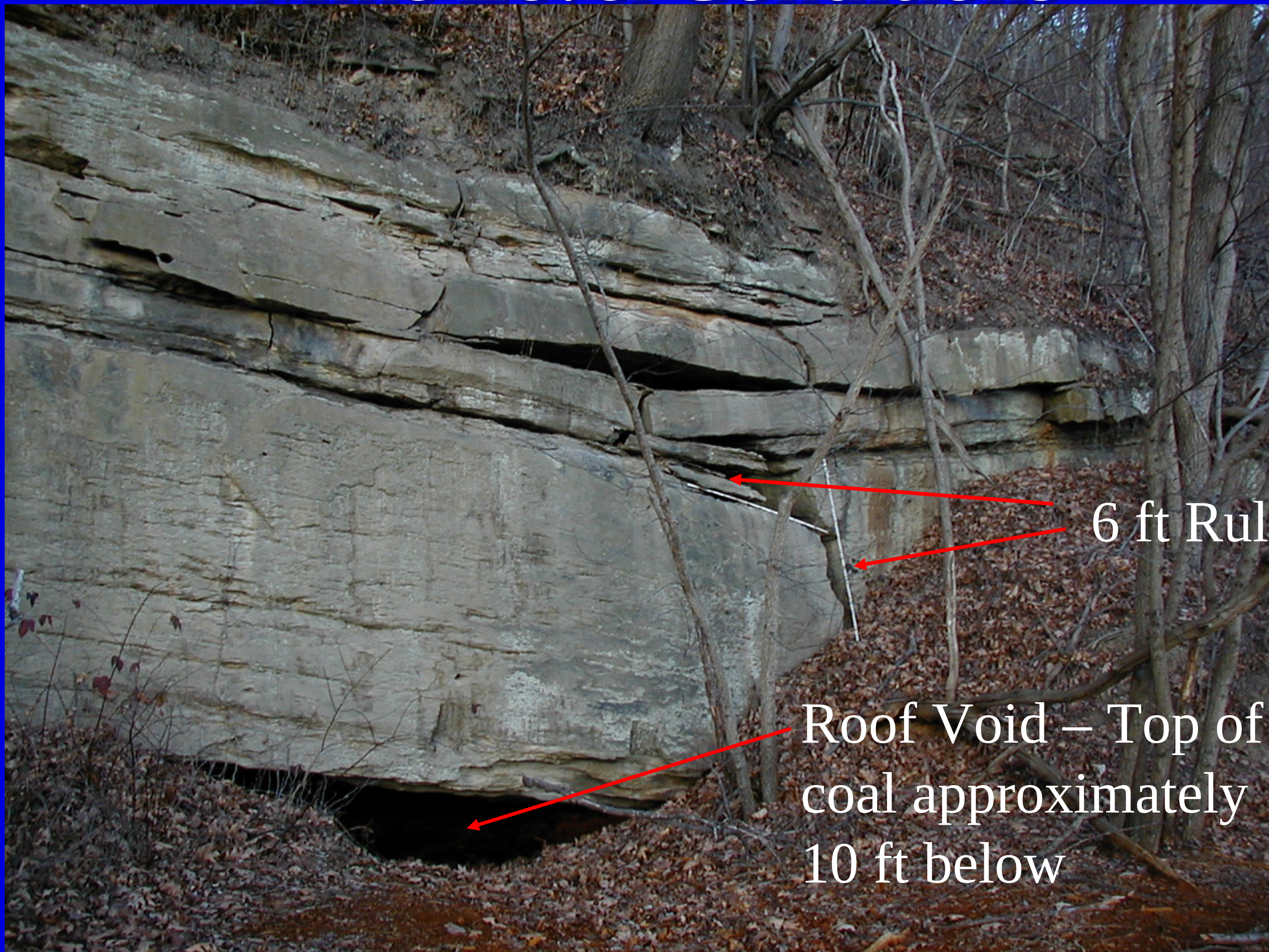
Mine Level Conditions



Caving of Main Sandstone Roof

Note – What would happen to a deep foundation passing thorough this material?

Mine Level Conditions



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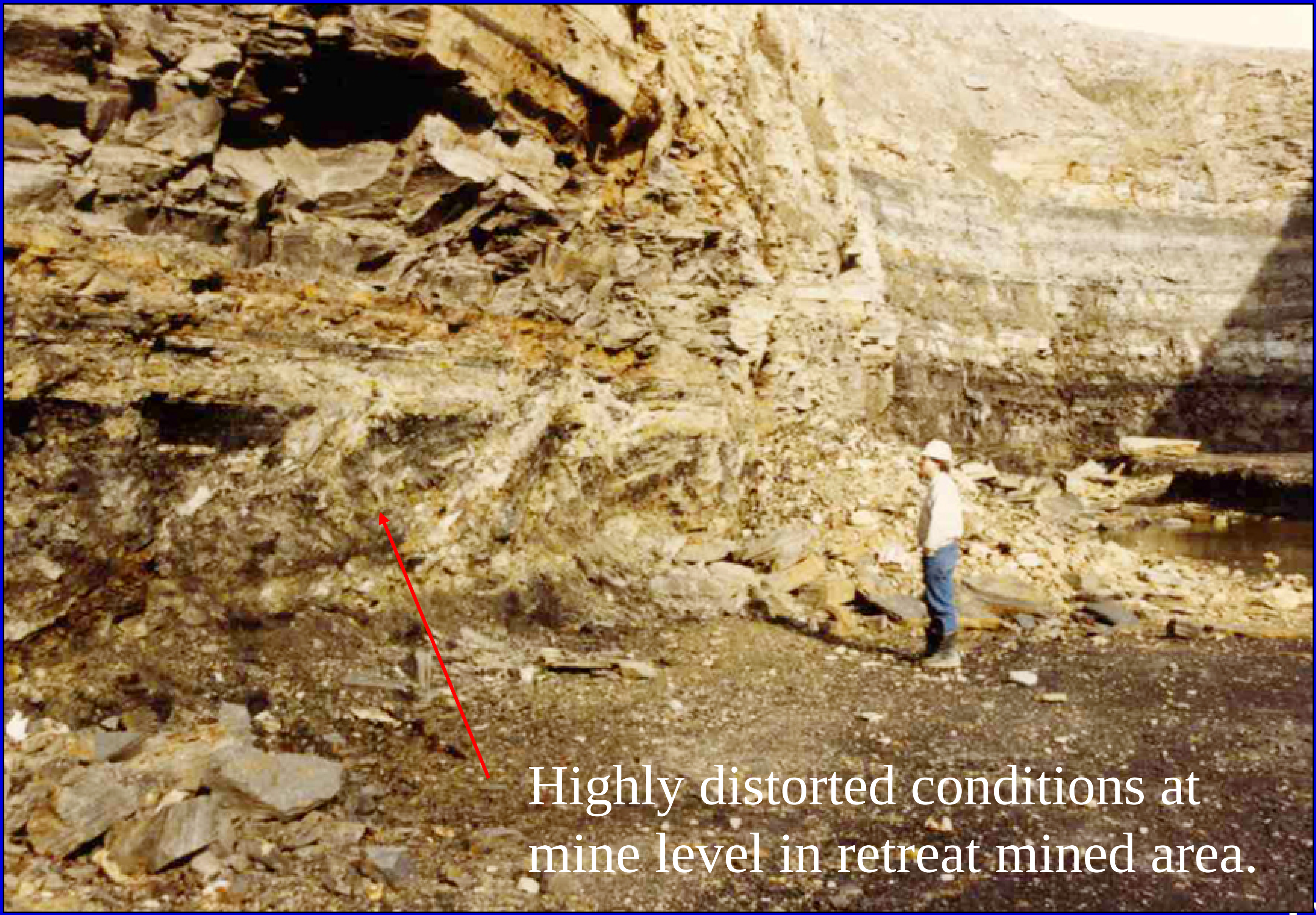
Mine Level Conditions



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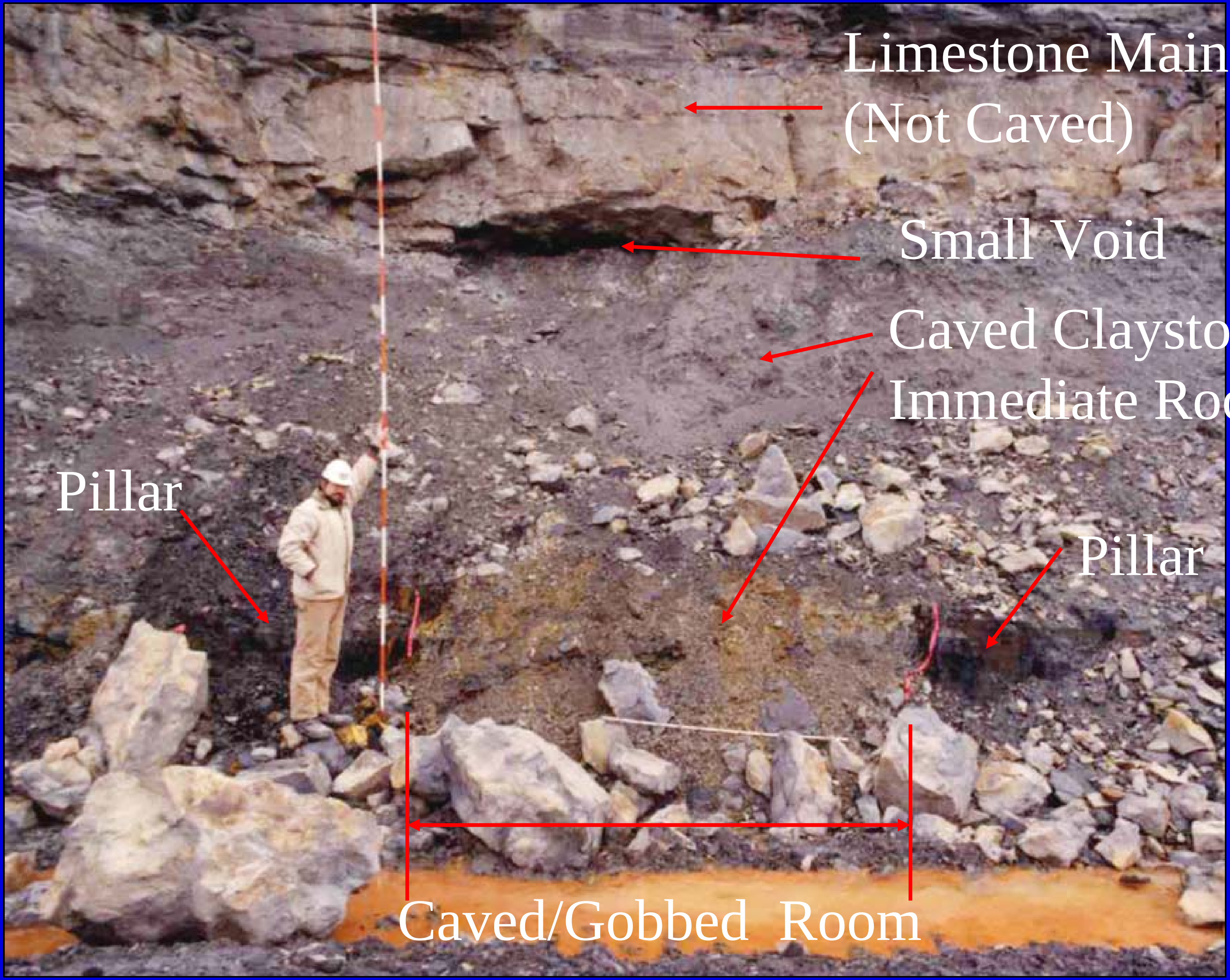
Mine Level Conditions



Mine Level Conditions

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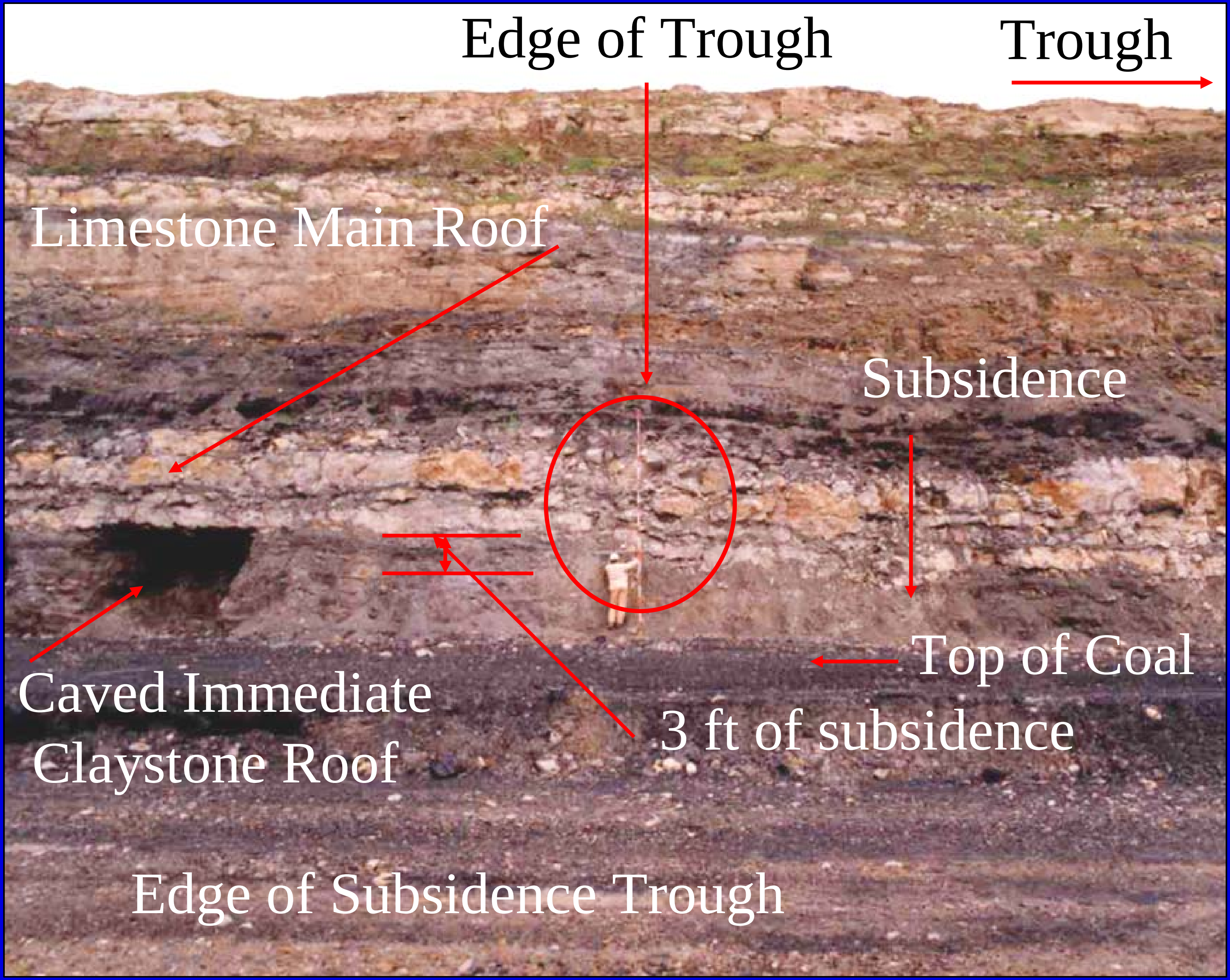
Mine Level Conditions



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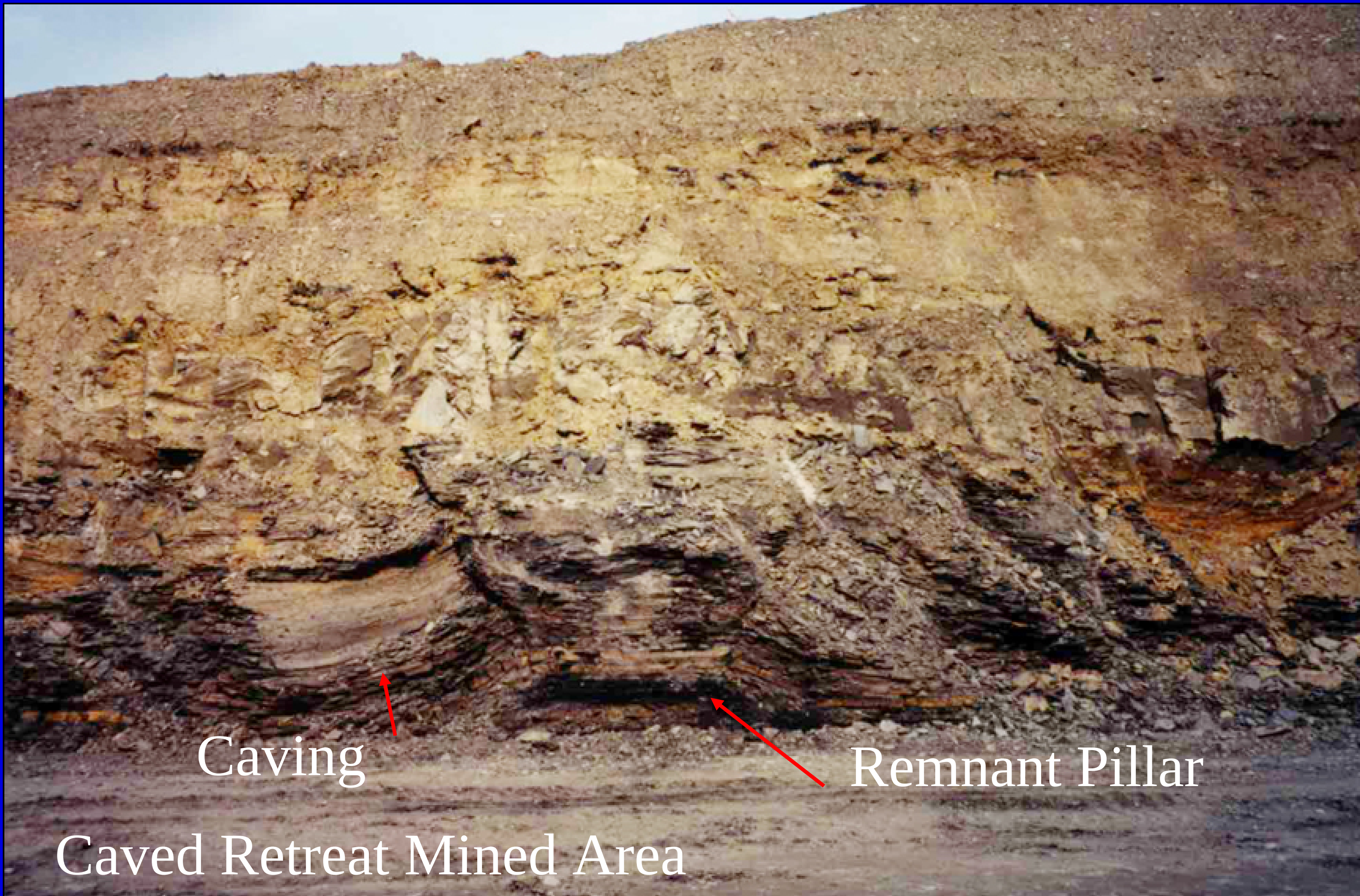
Mine Level Conditions



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Mine Level Conditions

Totally Caved Roof

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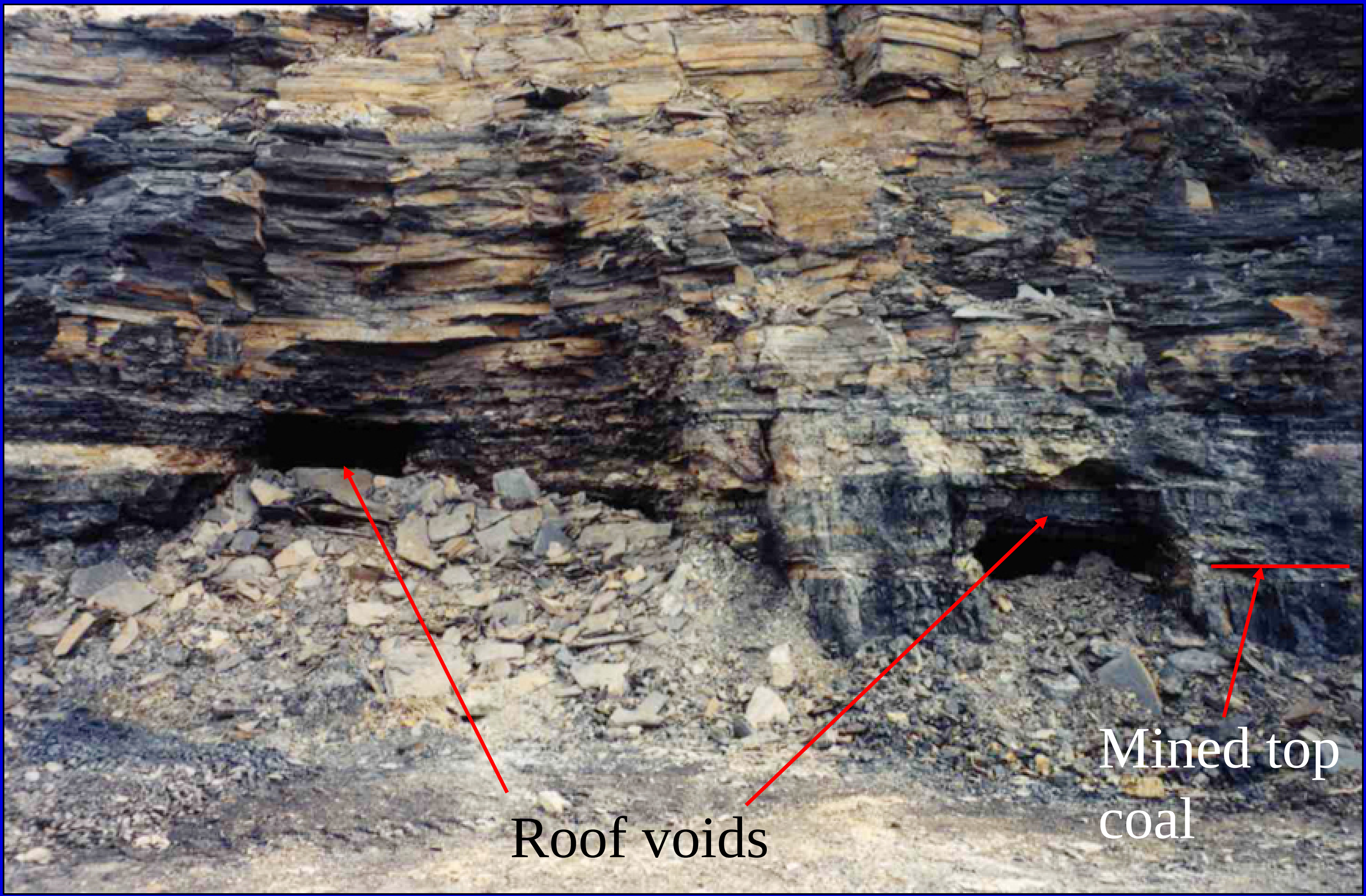
Mine Level Conditions



Roof Voids Due to Collapse of Immediate Roof

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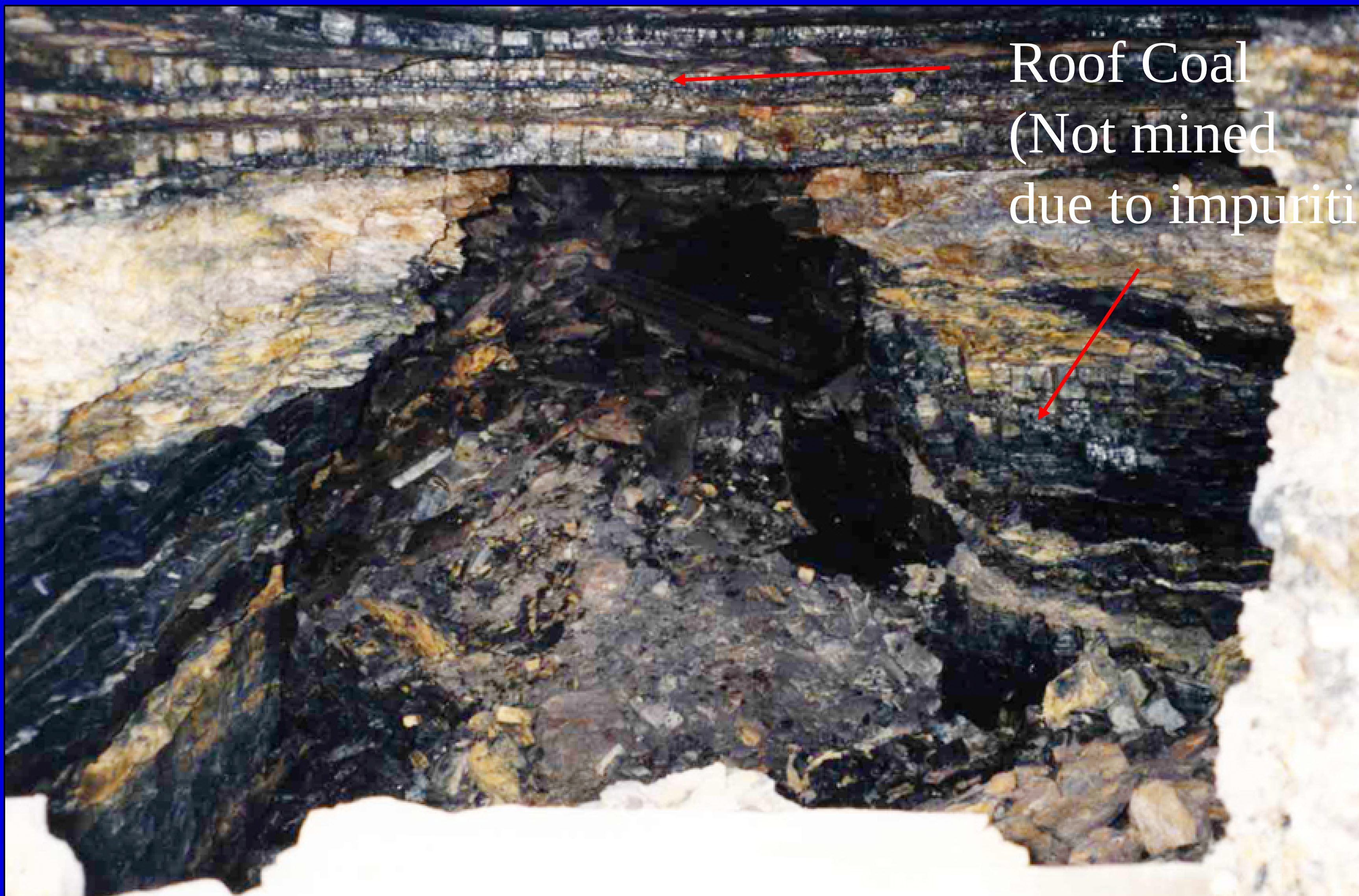
Mine Level Conditions



View of roof void and rooffall

Mine Level Conditions

View of roof void and underlying rooffall

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Mine Level Conditions

Entry in 3 ft seam

Stabilization

- Grouting is usually performed in the sinkhole prone zone where the rock cover is < 100 ft due to being cost prohibitive at greater amounts of cover.
- Grout holes are usually 6-inches dia. on a 25 to 30 ft offset grid, sometimes based on mine map.
- Angle of draw impacts are usually mitigated by extending the grouting 15 ft + a 15º angle to mine level beyond the edge of the facility.

Stabilization

- Typical Grouting Materials
  - Cement Fly Ash Grout
  - High Slump Concrete
  - Low Slump Concrete

Stabilization

- Example Cement Fly Ash Grout Properties
  - Fly ash (Class F) – 65%
  - Cement – 9%
  - Fly ash: Cement – 7:1
  - 7 day strength – 300 psi
  - Flowability – 25 to 35 second flow cone value for saturation grouting of mine workings and thickened as needed, may flow over 100 ft

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Stabilization

- Example High Slump Fly Ash Concrete Properties
  - Fly ash (Class F) – 45.4%
  - Cement – 6.3%
  - Coarse Aggregate – 14.4%
  - Fine Aggregate - 14.%
  - Fly ash: Cement – 7.2:1
  - Strength – 300 psi in 7 days
  - Flowability – 8 to 10 inch slump, may flow over 80 ft in open mine workings

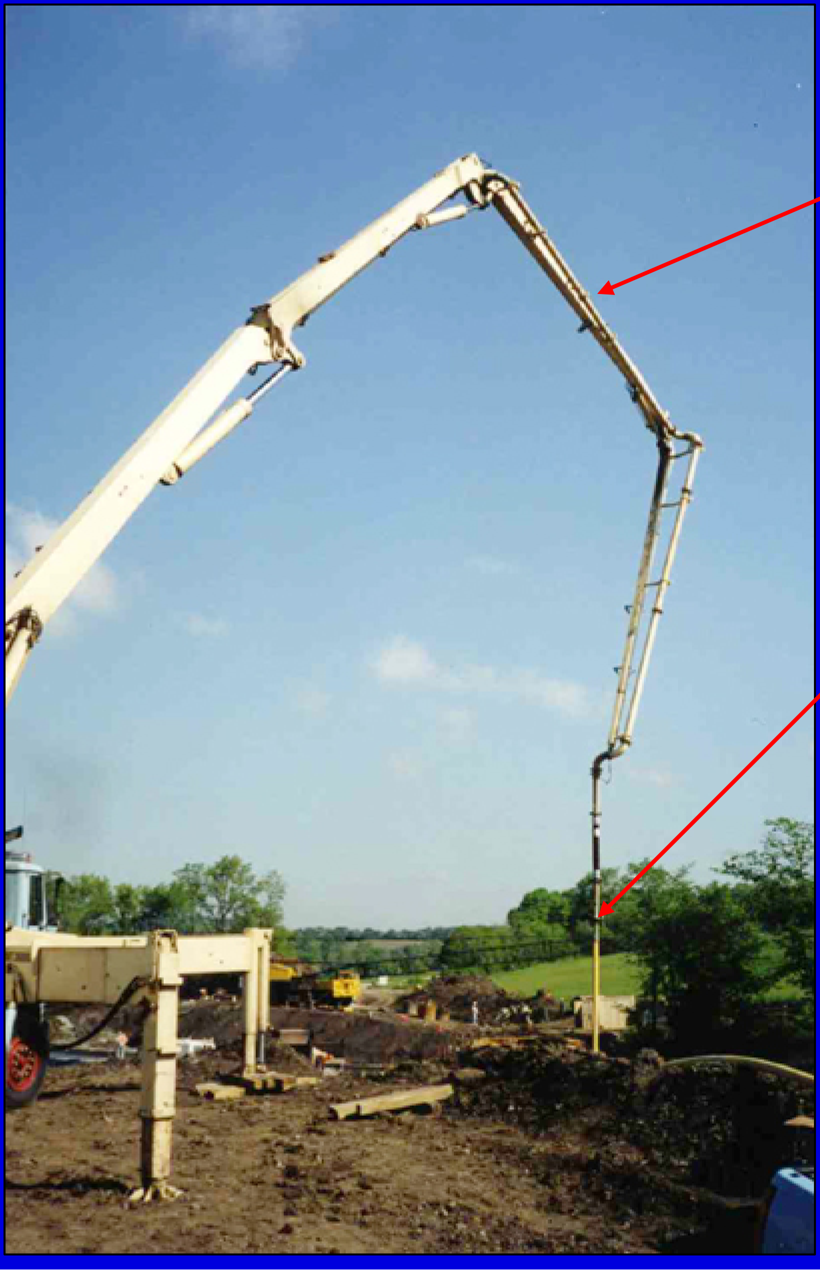
Stabilization

- Example Low Slump Fly Ash Concrete Properties
  - Fly ash (Class F) – 50.1%
  - Cement – 6%
  - Coarse Aggregate – 13.9%
  - Fine Aggregate - 13.9%
  - Fly ash: Cement – 8.4:1
  - Strength – 300 psi in 7 days
  - Flowability – 3 to 4 inch slump

Stabilization

Typical Air Track Rig

Stabilization



Concrete Pump Truck Boom

Grout Tube

Note: Extra head on grout due to height of boom helps to increase take.

Pumping Grout into Grout Hole

Stabilization

- Base grout type and consistency on anticipated mine level conditions.
- Be prepared to make modifications to mix and procedure.
- Use a grout strength based on 3 or 7 days to help the grout set up in the cool, moist, and sometimes flooded conditions at mine level. This helps reduce potential for erosion of grout due to mine water flows.
- Early strength also helps to account for impacts from mixing of the grout with mine water as it flows in the mine workings.

Stabilization

- Saturation Grout Application
  (25 - 35 sec. flow cone value)
  - caved and broken areas,
  - roof voids of limited lateral extent,
  - solidify rooffall below extensive roof voids,
  - pillars, and
  - open voids at mine level to solidify rooffall or loose material on the floor of the mine.
  - The mix can be thickened if large takes occur and the grout cannot be tracked in adjacent borings.

Stabilization

- Saturation Grout Application Continued
  - The 25 to 35 second flow cone value grout (“creamy soup” consistency) can flow into fractures as small as ¼-inch in width.
  - This flowability enables the grout to encapsulate rooffall, thus creating a solidified mass. Thicker mixes may not be able to penetrate into the rooffall and therefore, flow over it.
  - This consistency grout has been tracked to flow at least 100 ft in a retreat mined area where caved and broken rock was encountered in the grout holes.

Stabilization

- High Slump Concrete Application (8 to 10 inch Slump)
  - Open voids at mine level or
  - roof voids of significant lateral extent.
  - Usually used where voids are > 3 ft

Stabilization

- Low Slump Concrete Application (3 to 4 inch slump)
  - Create barriers in open mine workings.

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Stabilization

- Create barriers at perimeter of area
- Pump grout in an interior hole until it is filled, while checking grout travel in adjacent holes.
- Thicken mix if grout cannot be tracked after an appropriate amount, say 10 to 30 cy in Pittsburgh Coal.
- Discontinue grouting based judgment.

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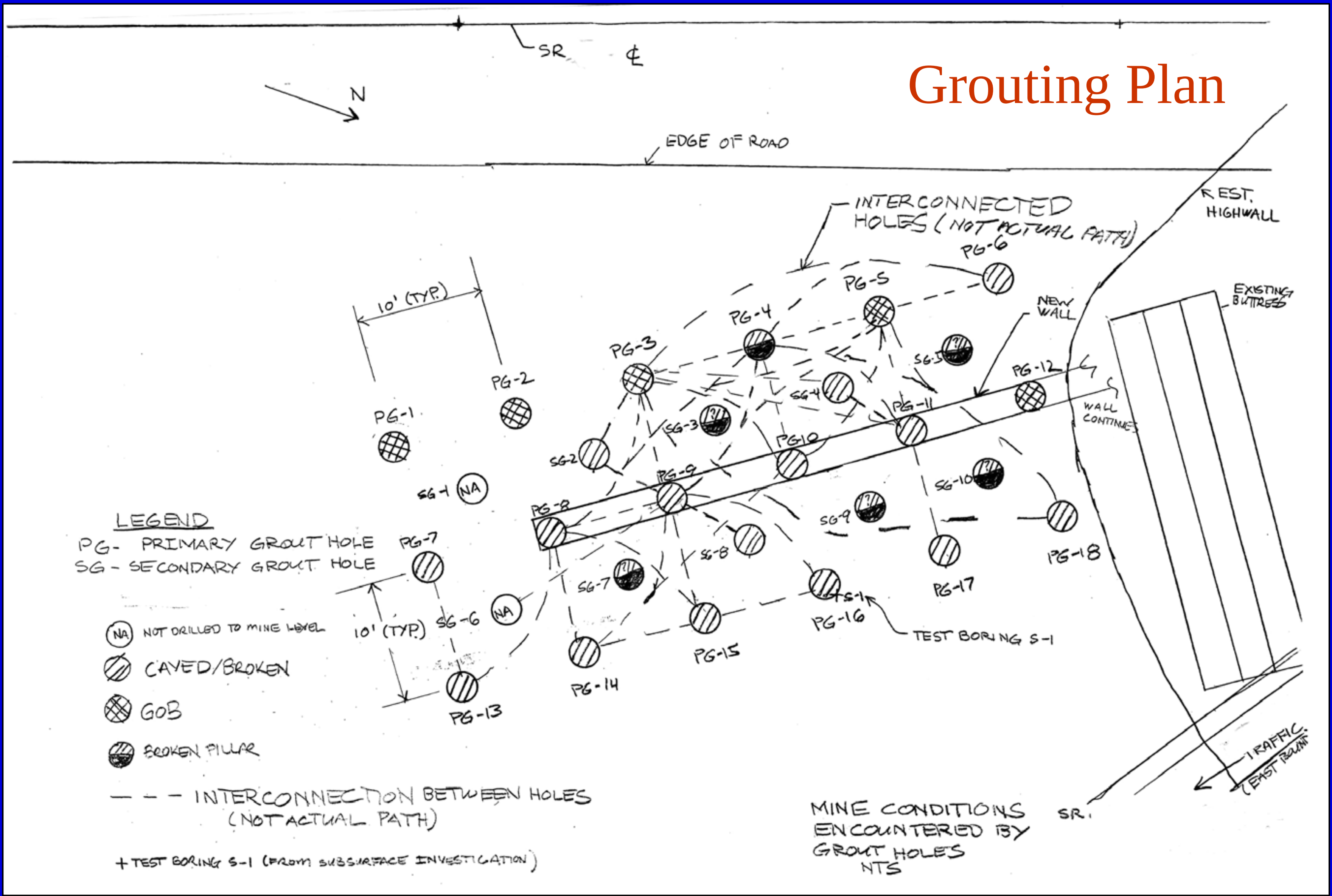
Stabilization

- Holes encountering solid coal can take if:
  - Fluid pressure from grout is sufficient to fracture side of pillar (approx. 100 ft in Pittsburgh Coal).
  - Pillar is “crushed”. A “crushed” pillar usually occurs in a retreat mined area where the pillar has been split and is overloaded and fails. It is usually indicated by air loss in pillar and action of tools during drilling.
  - The level of the grout in the hole reaches a fracture in the roof.

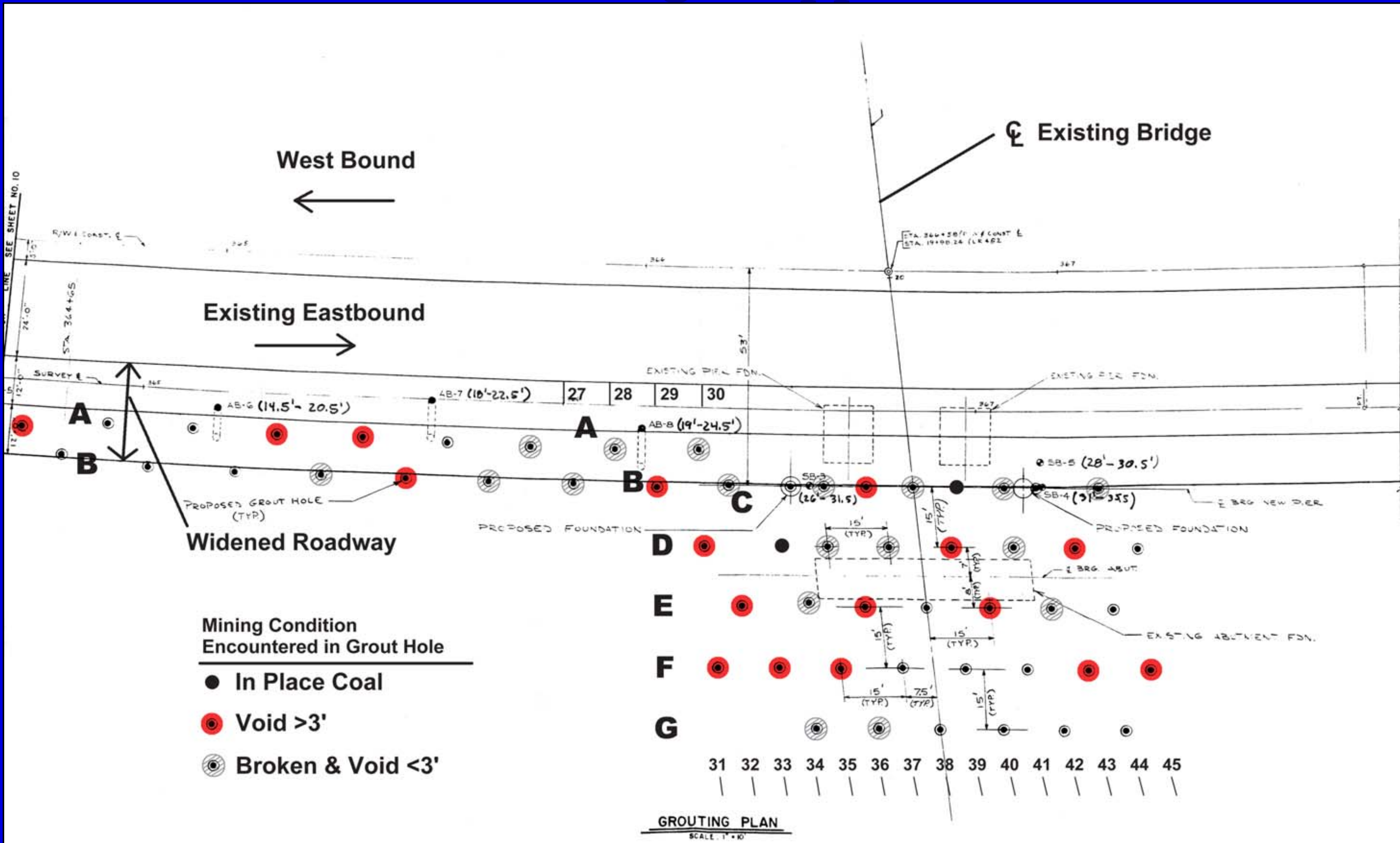
Stabilization

- Monitoring of Grout in Adjacent Holes
  - Allows extent of stabilization to be monitored during grouting.
  - More complete grouting since a large mass of grout is injected at one time.
  - Also allows determination if grout or gob has flowed up above mine level in adjacent holes so that redrilling is not performed due to the grout tube not being able to be inserted to the base of the mine.
  - Also helps to account for quantities

Stabilization



Grout Hole Plan for Roadway Widening & Bridge Support



Stabilization

Stabilization of shallow mine workings to support approach fill and mitigate subsidence impacts to drilled shafts for structure foundation.

Use of Flow Cone

- The flow cone is used for flowable backfill and other grouting operations, but has not been widely used in mine grouting since many mixes are developed based on strength. Its use enables the flowability to be matched to the purpose of the grout and provides a standard to describe the materials consistency instead of arbitrary nomenclature, such as “thick shake” or “creamy soup”.
- Flow cone tests should be performed near the point of injection, by using sampling port since pumping long distances may alter grout.

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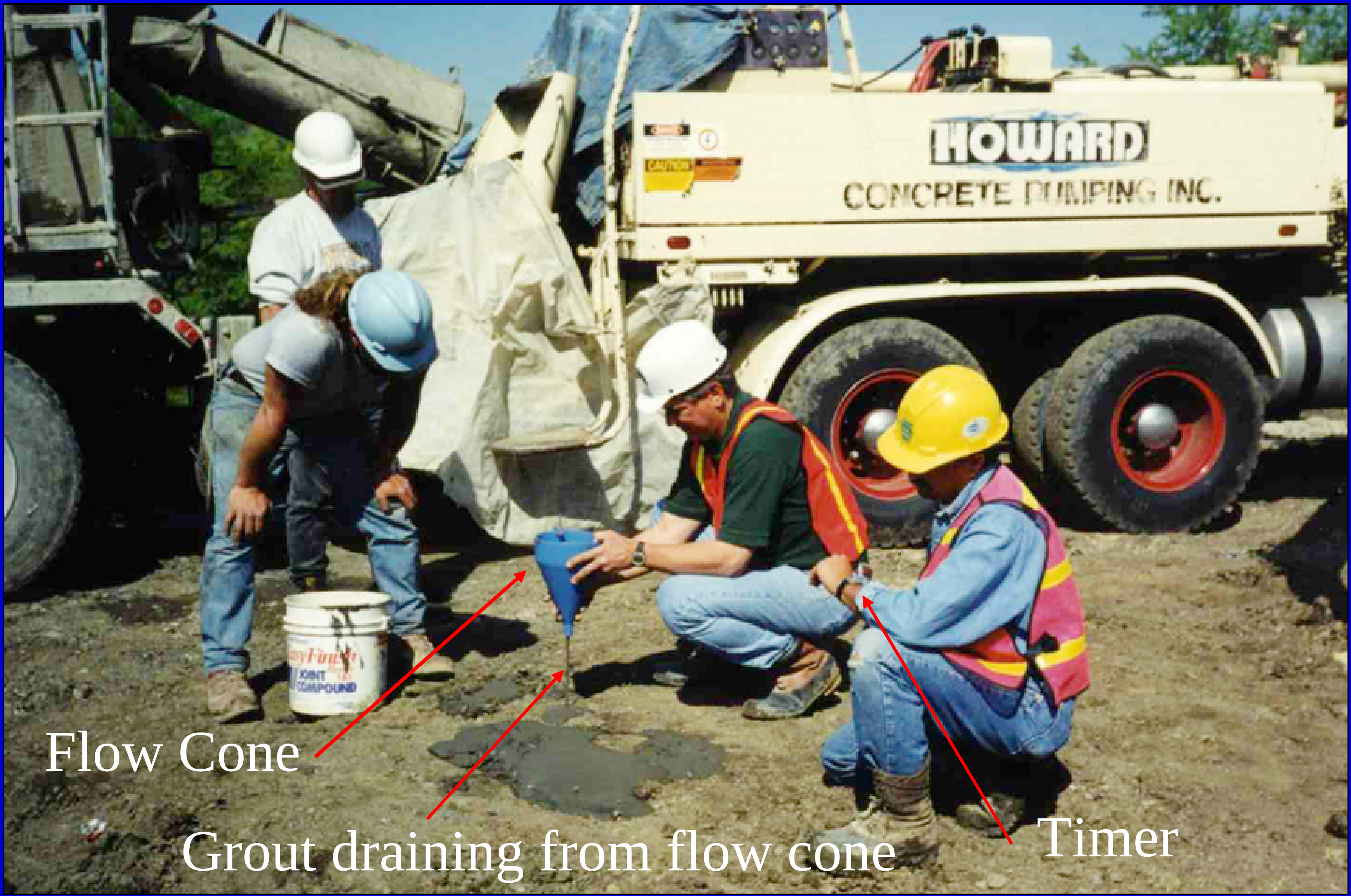
Flow Cone Test (ASTM C939)



Close up of flow cone

Grout depth indicator

Grout draining from flow cone

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Making Grout Cylinders

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Water Impacts

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Mine Water Impacts

Water being ejected from adjacent grout hole during drilling.

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Mine Water Impacts

- Mine water ejected from the borings:
  - Large quantities of mine water can be forced out of grout holes due to displacement by grout.
  - A plan to handle or treat mine water may be needed.
  - A “muddy” area that may require over-excavation can also result if the water is allowed to pond on the surface.

Mine Water Impacts

- Water flow in the mine may be impacted by grouting.
  - Displaced mine water may also flow out of entries near outcrops or seep through barrier pillars.
  - Mine water impacts can sometimes be dealt with by performing the grouting in a pattern that allows water displaced by the grouting to flow out of the area by not grouting all of the perimeter holes ahead of the interior grouting.

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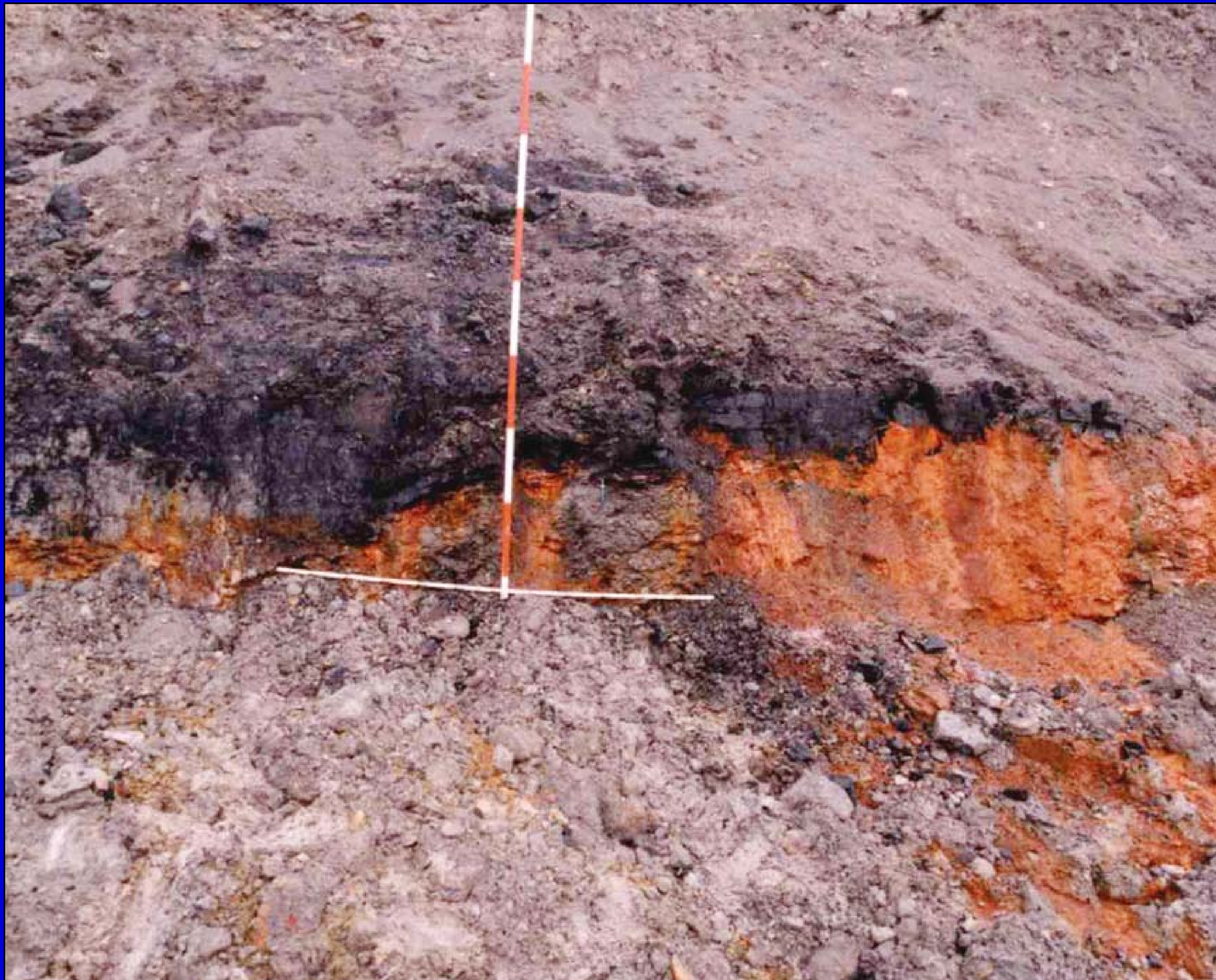

Introduction

- Grouting experience with abandoned mines in the Pittsburgh and Upper Freeport Coal Seams in Pennsylvania and West Virginia. Rock tunnel plugging experience in the anthracite region of PA.
- Direct observation of over 15,000 cy of grout injected in over 1,000 holes and oversite for over 10,000 cy of grout injected in over 400 holes.
- Investigation experience with sites in 8 states.
- Mine Fires in US and India.